# Signals and Circuits

## ENGR 35500

## Current, Voltage and Resistance

Chapter 1
1-1 to 1-3 (Circuit Terminology)
1-5 (Voltage and Power)

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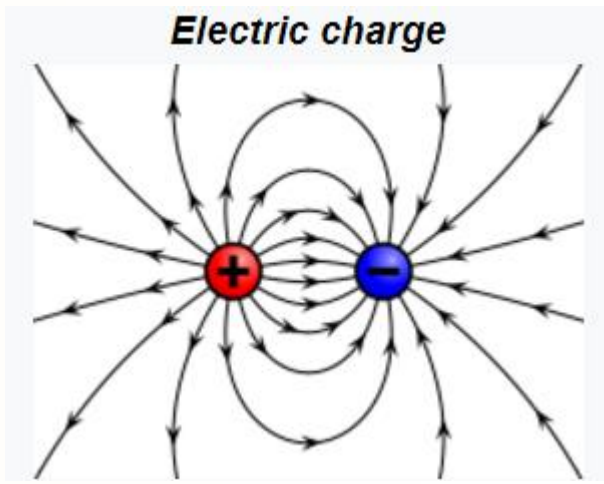
# Charge

- All matter contains a mixture of Neutrons, positively charged protons, and negative charged electrons;

- Electric charge is the physical property of matter that causes it to experience of a force when placed in an electromagnetic field.




- Like charges tend to repel each other; Opposite charges tend to attract each other.

# Charge

- Charge is measured in Coulombs (C).

- The charge of one electron is:

$$e = -1.602 \times 10^{-19} \text{ Coulombs (C)}$$

- The charge of a proton is equal in magnitude to the charge of an electron but opposite in sign (positive).

- Charge is always an integral multiple of *e.*

Practice: How many coulombs of charge do 9.34x $10^{16}$electron represent?



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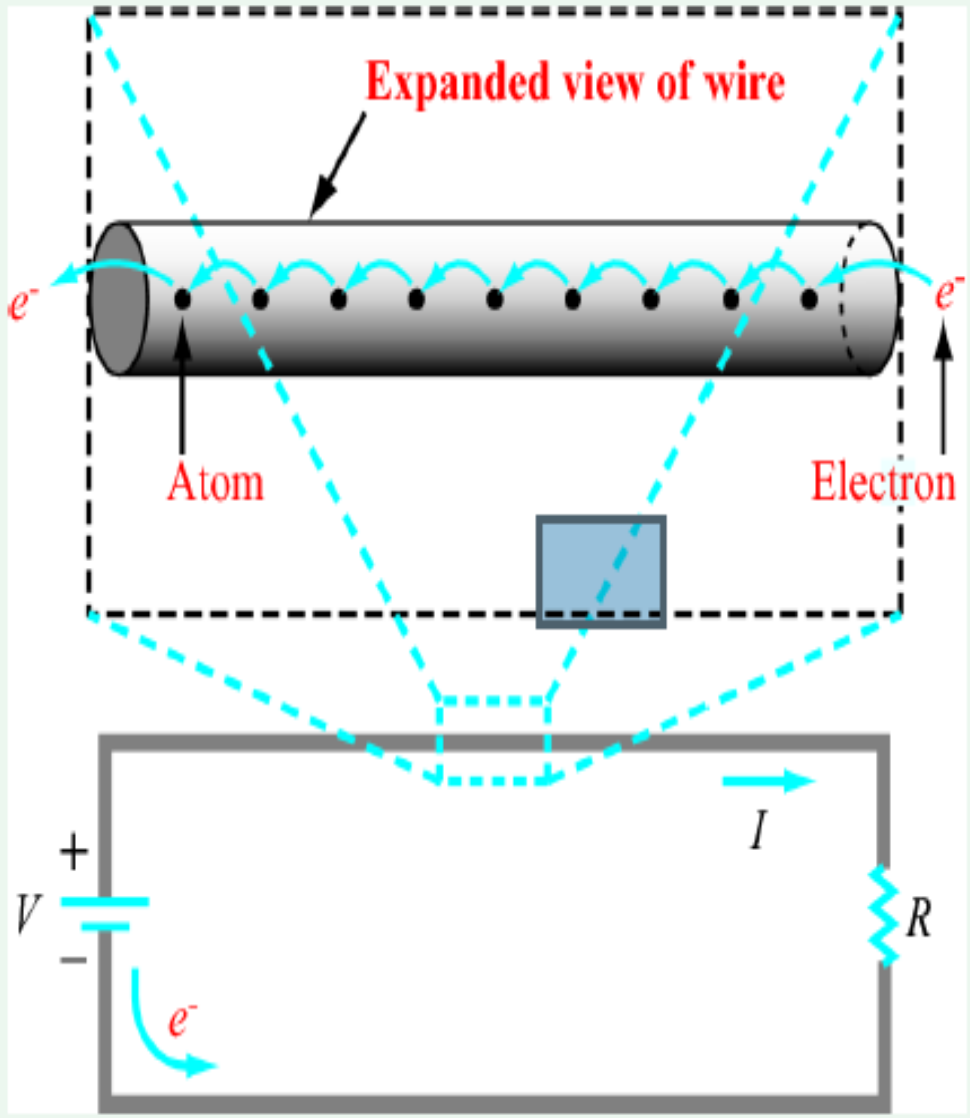
# Current

- **Ionization**
  - ➢The process of gaining or losing electrons.
  - ➢Significant in current flow.



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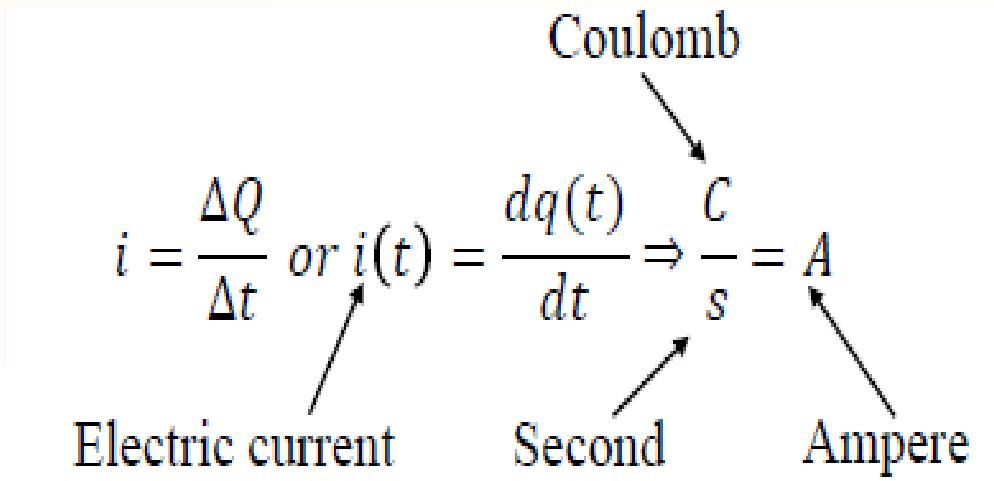
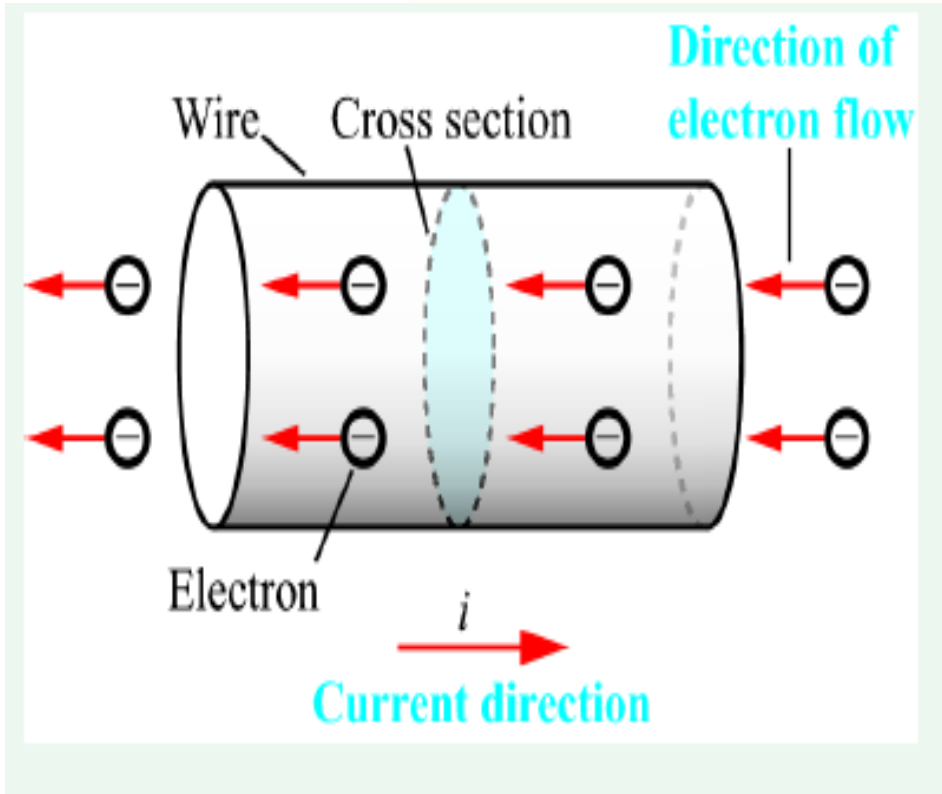
# Current

**Electric current** is defined as the time rate of transfer of electric charge across a specified boundary.



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# Current

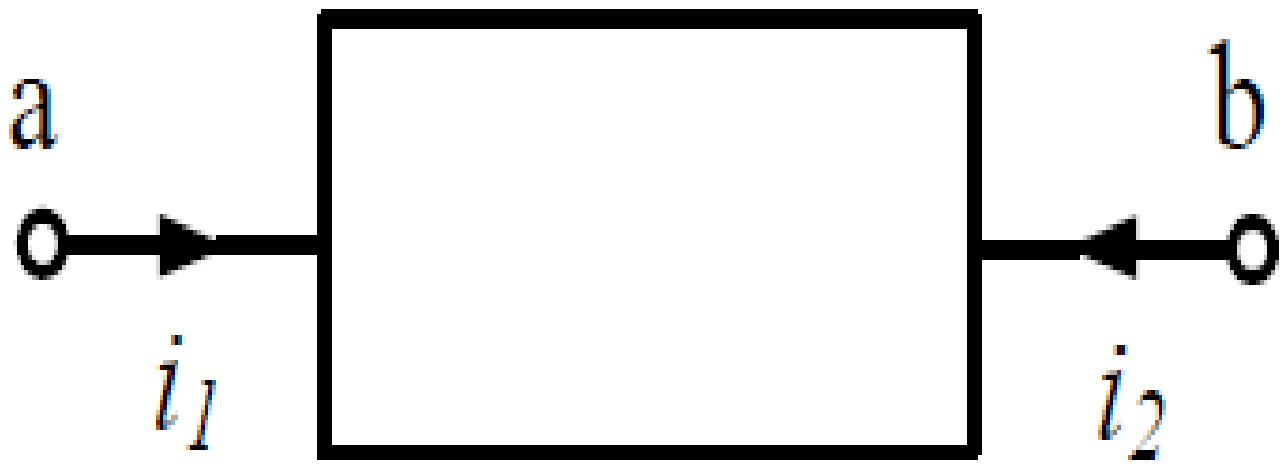
## Submultiples of the Amp

- **Milliampere (mA)**
  - Used more frequently than ampere.
  - Equal to 1/1000 of an ampere or .001 A.

- **Microampere (μA)**
  - Used more frequently than ampere.
  - Equal to 1/1,000,000 of an ampere or 0.000001 A.

# Current

- **Sign Convention**

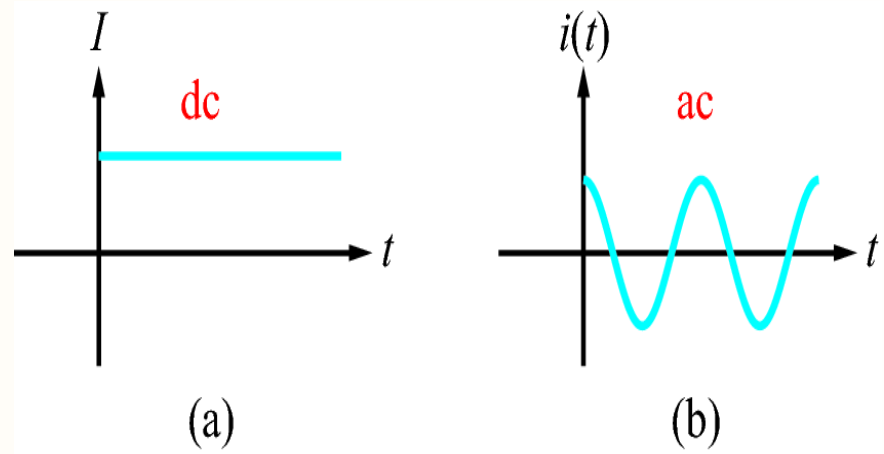


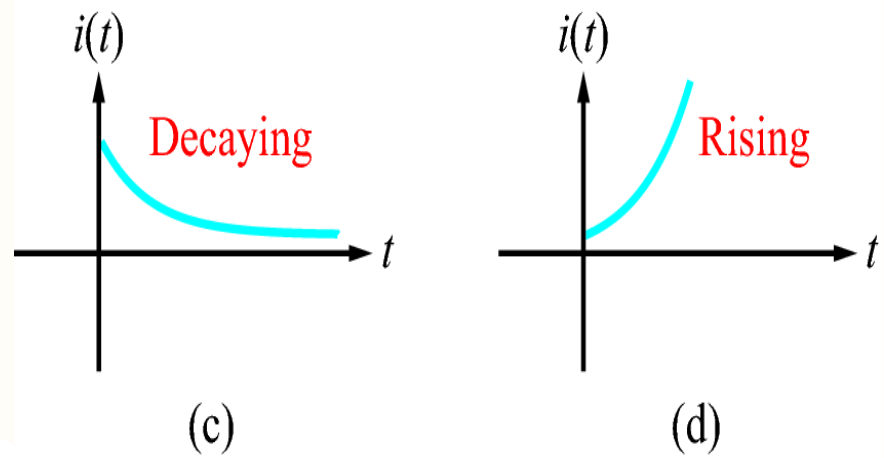

$$i_1 = -i_2$$

$$\text{e.g. if } i_1 = 3A \rightarrow i_2 = -3A$$

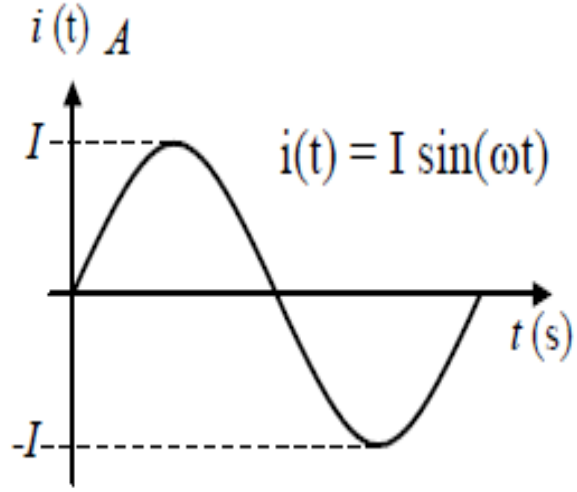
# Current

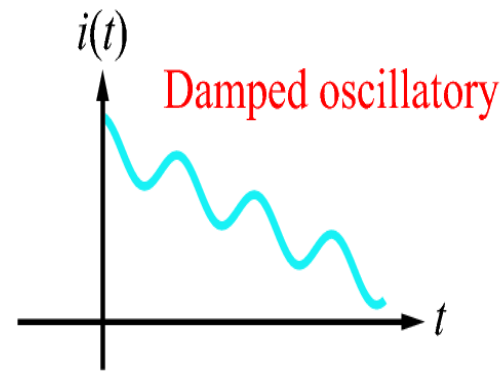
- **Variations of Current**
  - ➢DC (Direct Current)
  - ➢AC  (Alternating Current)




Sinusoidal current → Alternating current (AC)



# Current

- Since $i(t) = \frac{dq(t)}{dt} \Rightarrow q(t) = \int_{-\infty}^{t} i(t)dt + \ q(-\infty)$

Where *q(-∞)* is the initial charge at the beginning of the time

Example: Let q(t) = 12t C $\Rightarrow$ $i(t) = \frac{dq(t)}{dt} = 12\ A$

Example: Let i(t) = Mt A, $t \geq 0$, where M is a constant and q(0) = 0. Find the charge?

$$q(t) = \int_{-\infty}^{t} i(t)dt + qi = \int_{0}^{t} Mtdt + \overset{0}{\cancel{q(0)}} = \frac{Mt^2}{2}\ C$$

# Current

- **Exercise**

  If the current flowing through a given resistor in a circuit is given by $i(t) = 5(1 - e^{-2t})$ A for t>=0, determine the total amount of charge that passed through the resistor between t=0 and t=0.2s

$$\Delta Q(0, 0.2) = \int_0^{0.2} 5\left(1 - e^{-2t}\right)dt$$

$$= \left(5t + 2.5e^{-2t}\right)\Big|_0^{0.2}$$

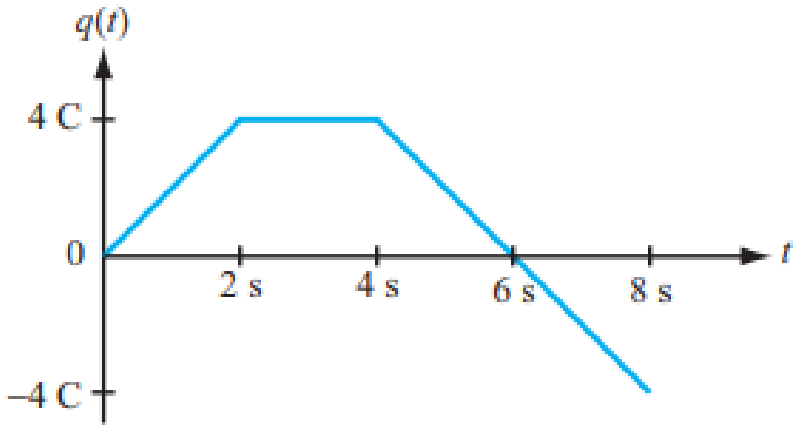
$$= \left(5 * 0.2 + 2.5e^{-2*0.2}\right) - (5 * 0 + 2.5)e^{-2*0}$$

$$= 0.176C$$

# Current

## Practice

**The plot displays the cumulative amount of Charge q(t) that has entered a certain device up to time t. Please plot the current vs time.**



# Voltage



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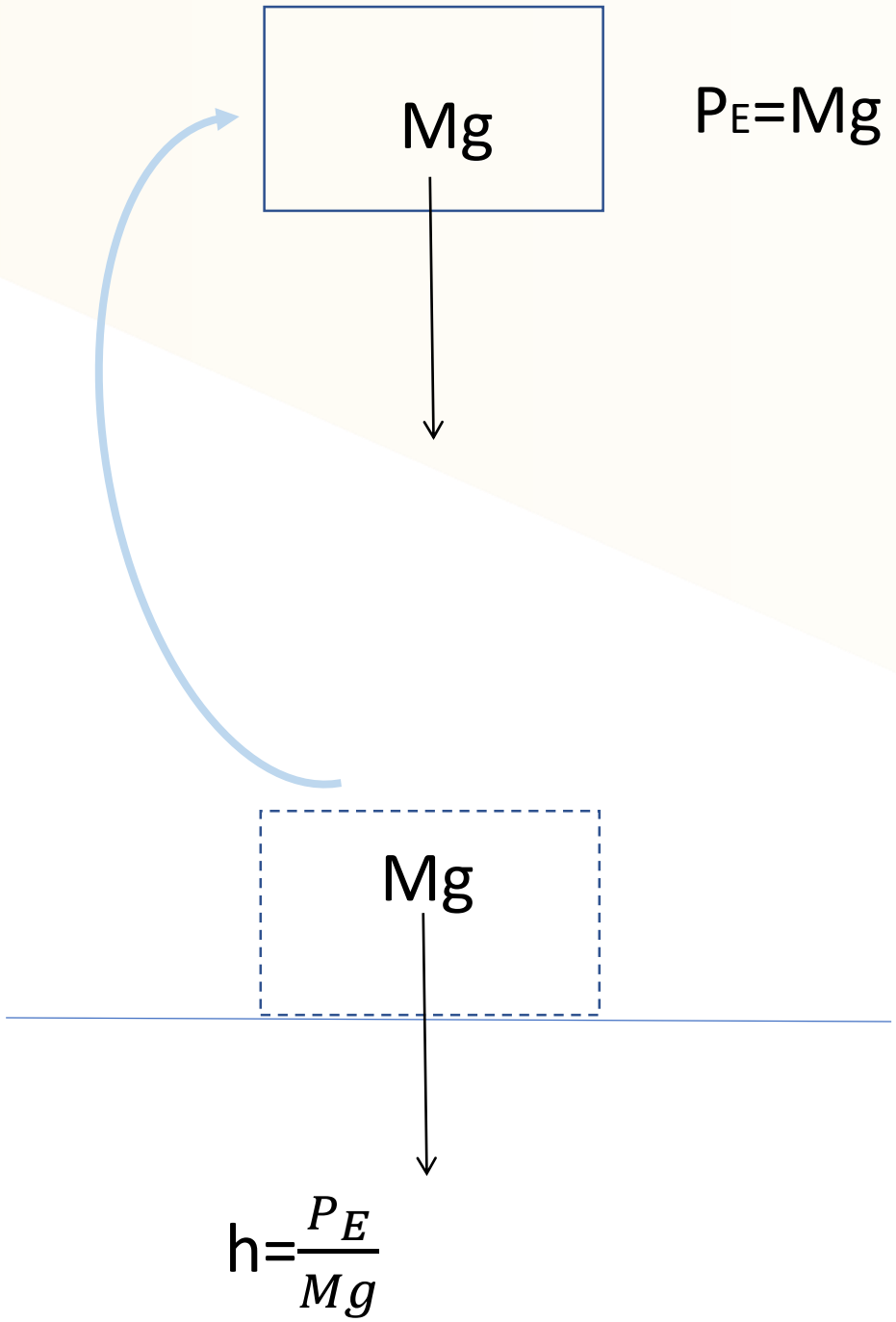
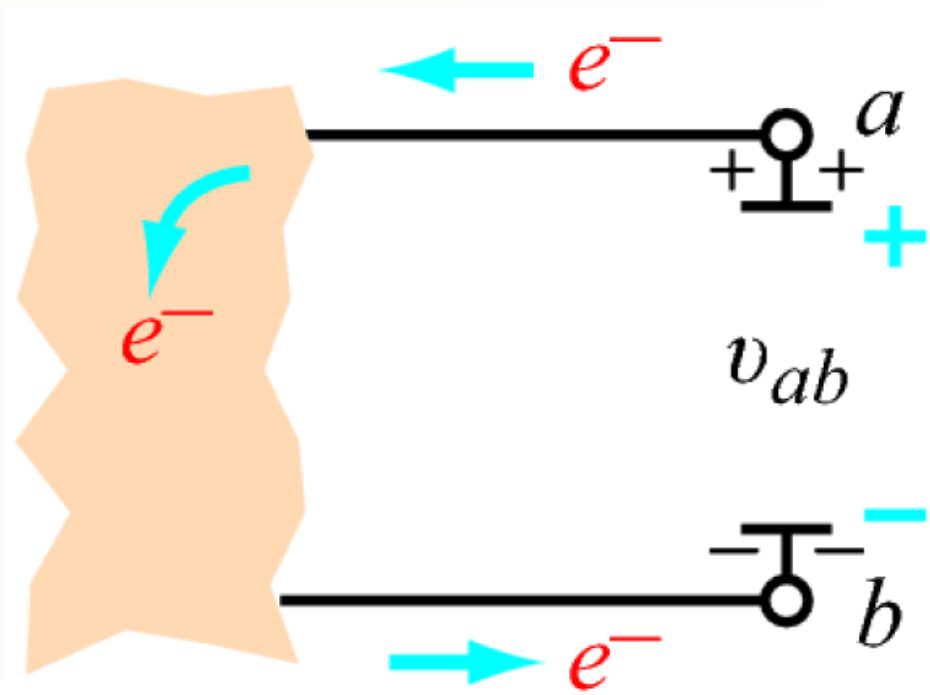
# Voltage




$P_E$=Mg x h

VS

Electromagnetic force




Energy expenditure: *dw*

Charge involved: *dq*



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# Voltage

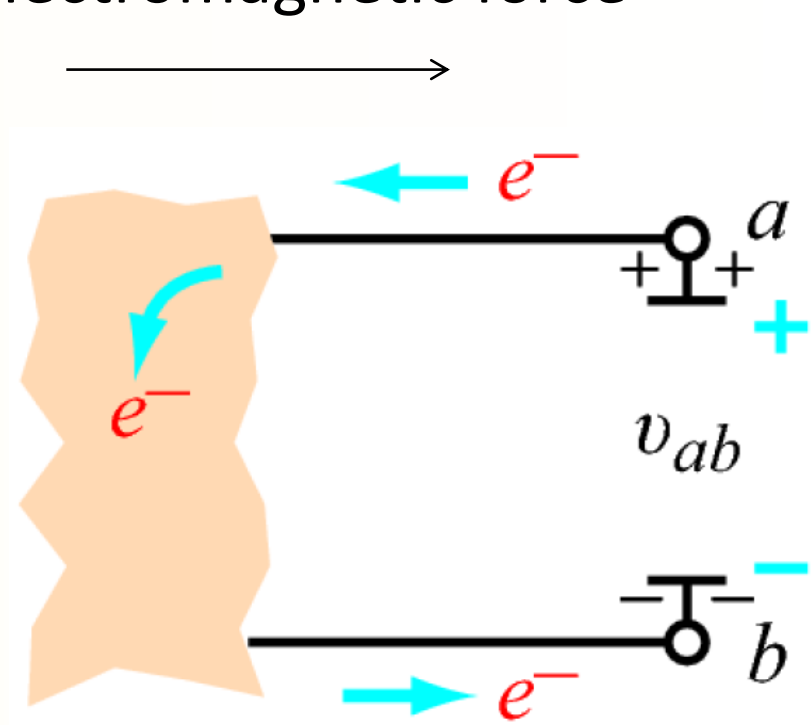
**Voltage** is a measurement of the expenditure of energy relative to the amount of charge involved.

$$V_{ab} = \frac{dw}{dq} \quad \begin{array}{l} \leftarrow work\ in\ Joules\ (J) \\ \leftarrow charge\ in\ Coulombs\ (C) \end{array}$$

Voltage

Unit:

$$Volts\ (V) = \frac{J}{C} \leftarrow 1\,\mathrm{J} = 1N \cdot m\ (Newton\ Meter)$$




Energy expenditure: *dw*
Charge involved: *dq*

Voltage between location ***a*** and location ***b*** is the ratio of ***dw*** to ***dq***, where ***dw*** is the energy in joules required to move (positive) charge ***dq*** from ***b*** to ***a*** (or negative charge from ***a*** to ***b***).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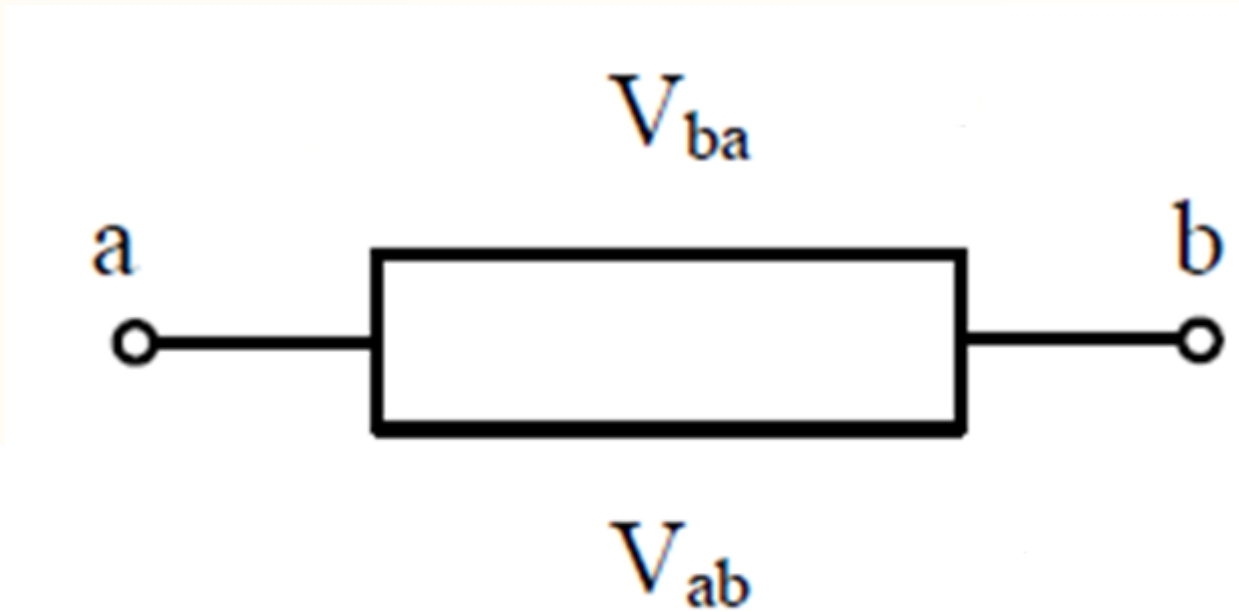
# Voltage




$$V_{ab} = - V_{ba}$$

$\boldsymbol{v_{ab}}$ emphasizes the fact that it is the voltage deference between points ***a*** and ***b***; and point ***b*** is the reference.



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# Voltage

$$v_{ab} = v_{ac} - v_{bc}$$



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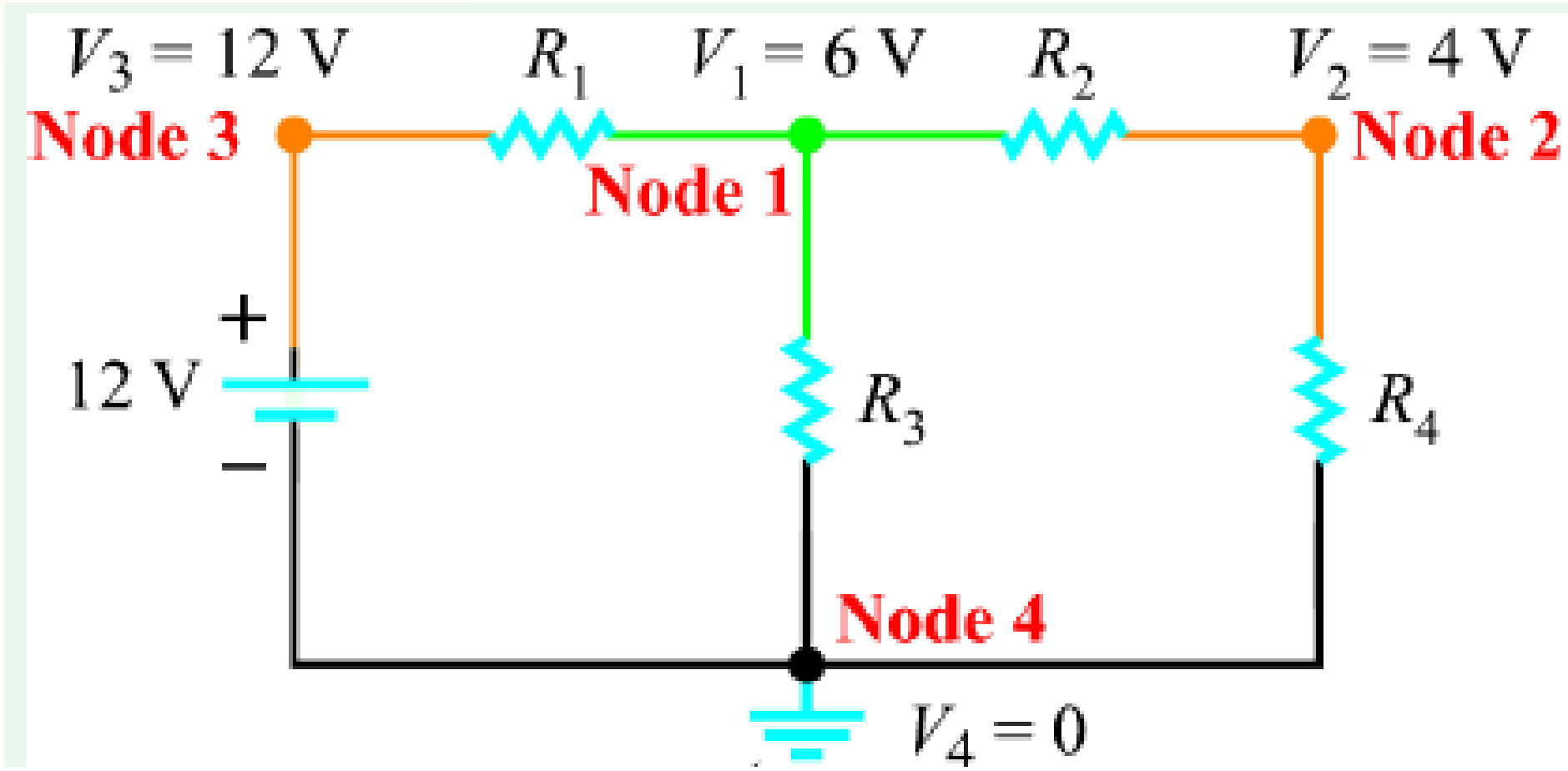
# Voltage

***ground***



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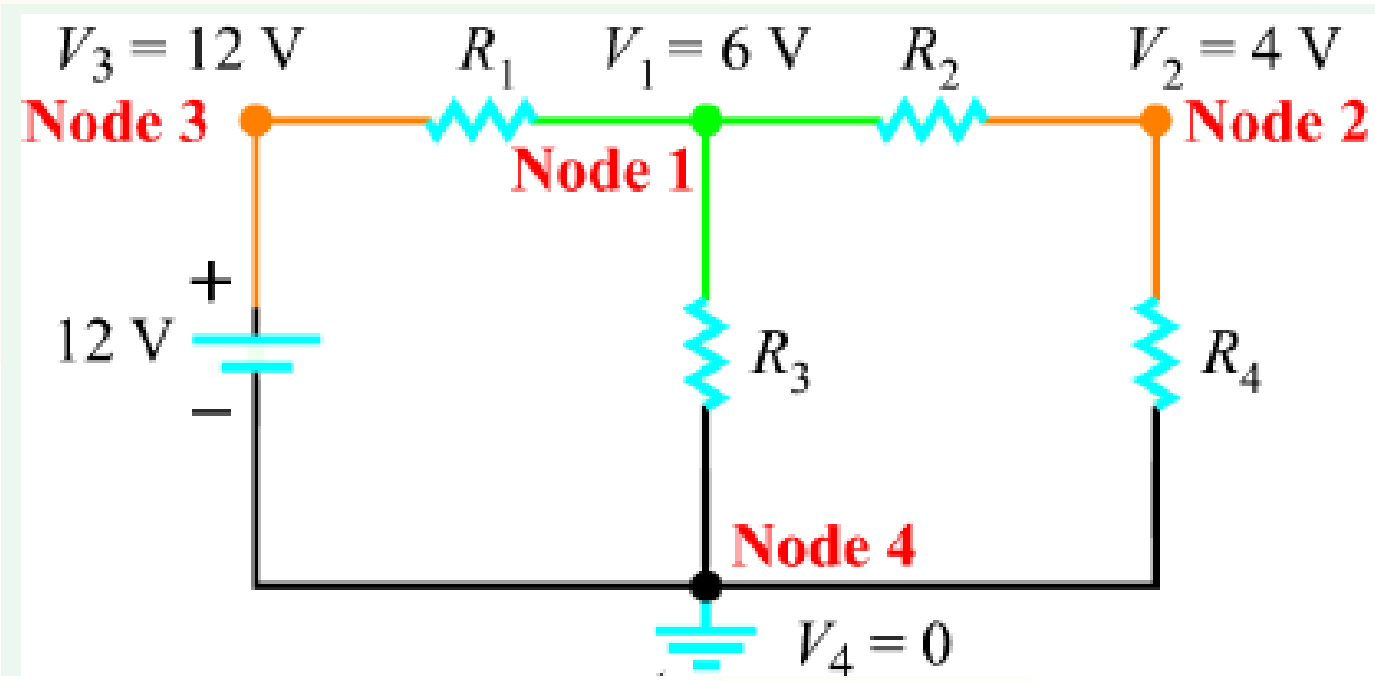
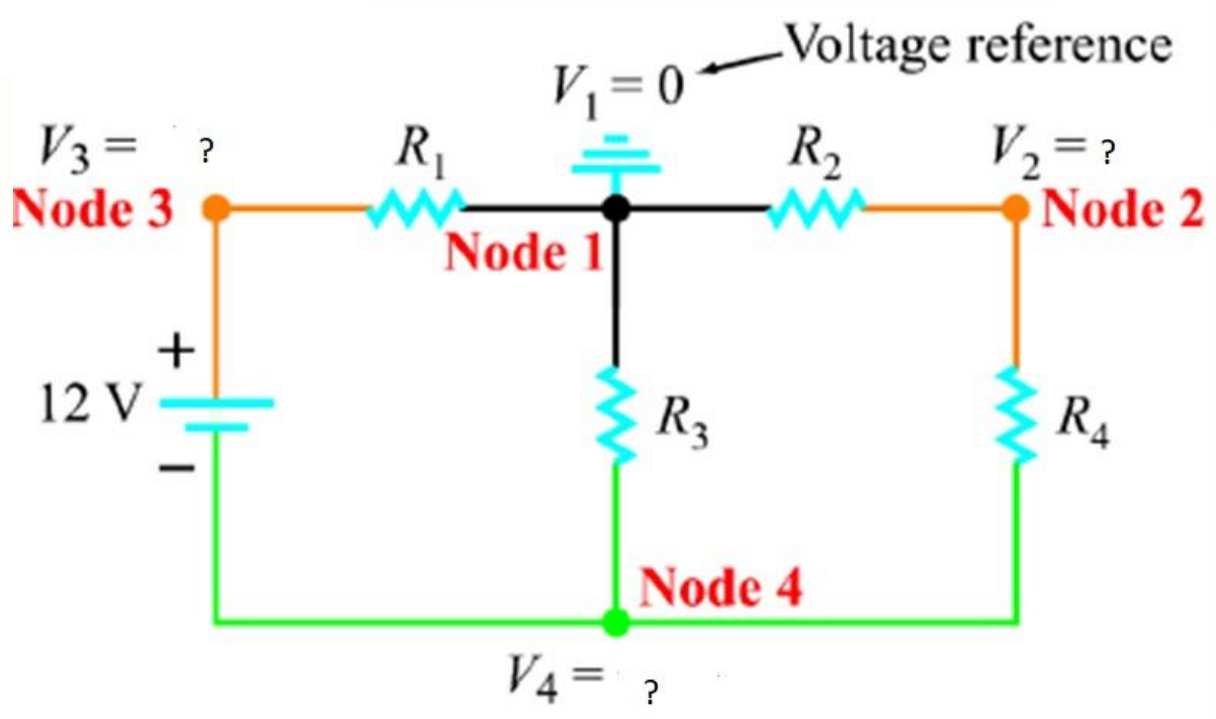
# Voltage


$V_3 = 12$ V
$R_1$
$V_1 = 6$ V
$R_2$
$V_2 = 4$ V
Node 3
Node 1
Node 2
+
12 V
−
$R_3$
$R_4$
Node 4
$V_4 = 0$


$V_1 = 0$
Voltage reference
$V_3 =$ ?
$R_1$
$R_2$
$V_2 =$ ?
Node 3
Node 1
Node 2
+
12 V
−
$R_3$
$R_4$
Node 4
$V_4 =$ ?



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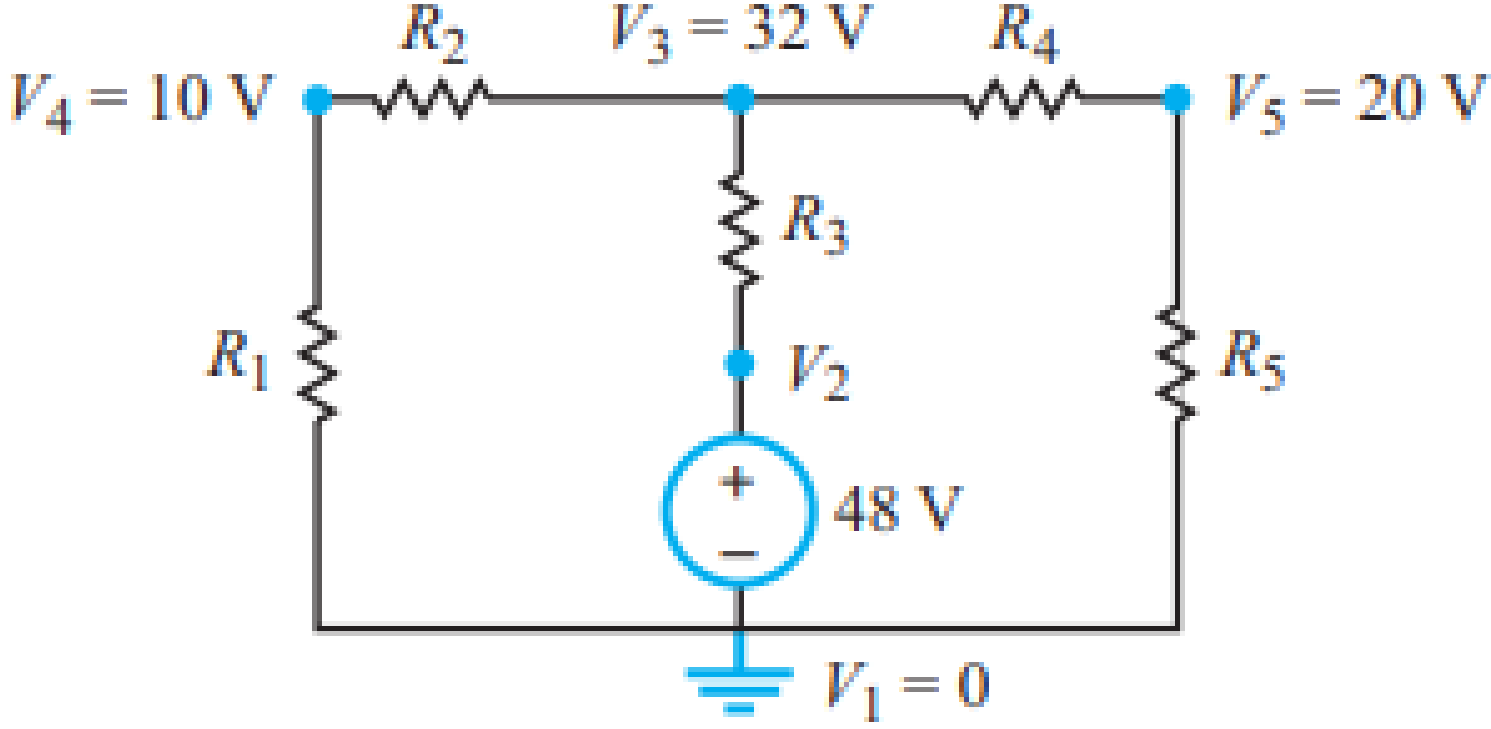
# Voltage

## Practice

(a) What is the voltage at node $V_2$?

(b) What is the voltage difference $V_{32} = V_3 - V_2$?

(c) What are the voltages at nodes 1, 3, 4, and 5 if node 2 is selected as the ground node instead of node 1?



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